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A DIGITAL MAGNETIC TAPE FORMAT FOR VELA-UNIFORM

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Preface

By a memorandum of 24 October 1962, the Advanced Research Projects Agency (ARPA) requested AFTAC to propose a standard digital tape format for use within the VELA-UNIFORM Program.

Investigation of the problem began with consideration of the procedures adopted by the Data Analysis and Technique Development Center (DATDC) in Alexandria, Virginia, for digitizing the analog signals recorded in real time on 14-channel magnetic tape conforming to AFTAC Magnetic Tape Recording Standards as described in Technical Report VU-62-1. It should be understood that conversion of analog signals to a digital format suited to direct computer input involves several steps; the first being that of conversion of the analog signals to digital form on one magnetic tape. Subsequent steps are required for rearrangement of the digital data in a format more logically suited to machine computation. During the later steps it is customary to add retrieval information to the tape in appropriate blocks. It is also customary to do any editing of the data, including discard of unwanted material, during the later steps. A very important fact to be recognized is that the format of the tape to be used as direct input to a computer program must be adapted first to the problem whose solution is desired, and second, to the make and type of digital computer which is used. Therefore, standardization of this final tape is limited at best, although some users could reach agreement if they had identical equipment and similar problems.

In view of the foregoing, this report is devoted to standardization of the digital format for tapes which can be exchanged by VELA participants, hereafter called the "Digital C" tape.

However, comments on the format of the final computer-input tape will be added as a matter of information to interested parties. These comments are based on questions and suggestions in reply to AFTAC correspondence with the several organizations concerned. An Appendix is included which lists the several organizations to which AFTAC correspondence was directed.

A DIGITAL MAGNETIC TAPE FOR VELA-UNIFORM

1. Introduction - Discussion of Requirements

1.1 Practical requirements of the VELA-UNIFORM standardized digital tape format dictate that it must be "IBM-compatible" because most organizations concerned have access to IBM equipment, or equipment compatible therewith. Also, since a particular analog tape format was established by AFTAC Technical Report VU-62-1, 25 October 1962, conversion to digital tape must be performed with available equipment whose input is adaptable to signals delivered by this analog tape, as well as, perhaps, analog tapes available from other sources.

1.2 While in principle any specified dynamic range in a digital system may be achieved by use of sufficient digits, a 12-bit (binary) number, corresponding to about 66 db in addition to sign sense, is considered sufficient. This infers that the analogue noise level corresponds to a 1-bit uncertainty, or "least-count," and that analogue signals exceeding some arbitrary maximum amplitude, limited to the maximum number expressible by 11 binary digits, will be registered as if they were clipped. (Obviously, the signal voltage can be adjusted to the digital range.) It also infers that the amplitude units are constant increments at all amplitudes within the 66 db range. Again, the digital range falls within the dynamic range of available amplifiers, some of which have a range greater than 70 db. However, this is a greater range than any known analogue magnetic tape system. Realistic measurements on these systems, in terms accountable to seismological practice, show that the useful limit is about 35 db. This is in terms of peak-to-peak noise to full peak-to-peak deviation, which corresponds to 50 db, rms noise to full peak-to-peak deviation.

1.3 Physically, the IBM-compatible tape referred to in this paper has a width of ½ inch, and accommodates seven tracks. One of these tracks is assigned for parity check of the bits recorded across the tape on the other six tracks. A system is described as "odd parity" when the binary digit inserted on this track is chosen to make the sum of the seven digits (bits) odd rather than even. We have chosen odd parity, which is in general use. A computer word of 36 bits (IBM 700 and 7000 series computers) requires six successive "frames" (rows of seven bits) along the tape, and a computer word of 48 bits (CDC 1604) requires eight successive frames. Hence the assignment of 12 bits per analogue value permits the packing of three values in an IBM format or four values in a CDC 1604 format. The packing density along the tape can be from 200 frames per inch to 800 frames per inch, the latter figure being achieved with the newer IBM high density system.

1.4 To sum up by example, 12 channels of original signal data, sampled 20 times a second, will produce 2880 binary digits for each second of time, 480 frames along the tape. This corresponds to 2.4 inches per second at 200 frames per inch, 0.85 inch per second at 556 frames per inch, or 0.6 inch per second at 800 registrations per inch, all of which are "IBM-compatible." However, lest it be assumed that the higher packing densities approach that possible with the original analog tape, it should be noted that the sampling rate of 20 times per second will in practice accommodate signals only up to four cycles per second, whereas the VELA-UNIFORM Standard Analog Tape will record at least 50 cps on an FM channel.

2. A Standardized Format for Digital Tape

2.1 Figures 1 and 2 diagram an IBM-compatible format for storage of binary digital data on tape. Figure 1 shows the pattern related to the CDC 1604 computer, the type is service at DATDC. Figure 2 shows the pattern related to IBM 700 and 7000 series. In each case the diagram represents a computer word, together with its check bits. Subscripts to the exampled values refer to the number system base, decimal or octal, while the binary notation is the usual one-zero combination. Only one value is represented in each diagram. Data can be packed three or four values to a word. Both diagrams represent an IBM-compatible arrangement of data, and either can be created and read at DATDC. However, before discussing use of this tape format, let us describe the process by which digital computer tapes are derived from analog recordings at DATDC.

2.2 The equipment used for analog-to-digital conversion at DATDC is termed "ANALOG-TO-DIGITAL SYBSYSTEM" (ADSUB). In addition to its obvious function of conversion, this ADSUB incorporates time code selectors which can read the VELA-UNIFORM time code on the analog tape. ADSUB is also connected directly to a CDC 160-A digital computer. ADSUB will digitize up to 14 channels of analog voltage simultaneously at rates up to 12000 values per second. The process is a sampling one, in which the several analog channels are sampled in rapid succession. Each sample is converted to a 12-bit binary value of the voltage, the converter being biased to make the octal value, 4000_8, correspond to zero volts, while 0000_8 and 7777_8 correspond to minus full scale and plus full scale voltage, respectively.

2.3 The procedures adopted by DATDC for conversion of VELA-UNIFORM analog magnetic tapes to digital form can be followed by referring to Figure 3. Blocks in this figure include four distinct digital tapes, only one of which, "Digital S" tape, is suited to computer input without further transfer. The "S" refers to "special" and implies only that arrangement suited to use at DATDC for some particular problem.

2.4 Figure 3 shows three major steps. The first step delivers "Digital A" tape which could be read by IBM equipment, but the data are packed with several values to a computer word and only a serial number identifies the tape. The second major step creates a "Digital B" tape, usually from several Digital A tapes. Here the original signal channels are written as a sequence of time series, and label information is included to produce a tape suited to filing in the DATDC library. The "Merging" instructions are part of the CDC 1604 program and control the arrangement of all data, including labels which come from punched cards. The dotted rectangle, "Digital Tape for X-Y Plot," simply indicates a provision for graphical readout, useful for study and checking of prior conversion processes. Finally, other CDC 1604 programs provide means for conversion of Digital B tapes to "Digital C" or "Digital S" tapes. The general format of Digital S tape is shown in Figure 1, with the qualification that it may have up to four values packed in the eight frames shown. The format of Digital C tape is the "IBM-compatible" tape to be provided to other users. It is the format of Figure 2.

2.5 In practice, the operator sets time code selectors on ADSUB to determine which portion of the analog tape will be digitized. Automatic search then locates the requested time code section and digitization begins. ADSUB provides the 160-A with an identifying number which will eventually become part of the label on Digital B tape. The station time code is also carried as a signal on Digital A tape as a separate "file" (block of data) for further transfer.

2.6 Subsequent transfer processes in Step 2 provide a library tape with appropriate and reasonably complete labeling. This Digital B tape is the one from which tapes for distribution or for computer input are derived, as shown in Step 3 of Figure 3. The Digital C tape is the particular "IBM-compatible" tape which now becomes the standard for VELA-UNIFORM programs. It is diagrammed in Figure 2 as having 200 frames per inch, and it will be supplied to other users in this density unless otherwise requested. However, in the fall of 1963, DATDC will be equipped to write tapes at either 200 or 556 frames per inch.

2.7 Summing up, the tape which will be supplied to other users is low-density (200 frames per inch) IBM-compatible half-inch tape, containing integers representing decimal values between minus 2048 and plus 2048. Each file on a tape contains one seismic signal channel of a single station, whether that is from a directional component or single element of an array. The files are separated by "end of file" marks. The last file of each seismogram is the digitized conversion of the station time, treated as if it were a seismic signal.

3. Labeling

3.1 At DATDC, the FORTRAN label routine arranges the digitized data into files (data blocks). Each file contains a time series of the digital values of a seismic signal channel. The first file is preceded by a label which contains information such as:

3.1.1 The seismogram number which is used for retrieval purposes.

3.1.2 The number of channels or elements in the seismogram, including the timing channel.

3.1.3 The number of digitized points per second of real time.

3.1.4 The number of digitized points per channel.

3.1.5 The world time reference of the first digitized point in the seismogram.

3.1.6 The order in which the channels appear on the tape.

3.1.7 The event name, date, station name, and other reference information.

3.2 At DATDC, FORTRAN programs are available for listing, changing or expanding the labels as desired, for retrieval of specified data, and for reconversion of signals to an analog form suitable for driving an X-Y plotter, where X represents the time axis, Y the signal amplitude.

4. Comments on Format and Code Conversions

Correspondence from several of the organizations concerned with digital processing of data in the VELA-UNIFORM program has indicated an interest in explicit formats covered by the term "IBM-compatible" and in specific arrangements of data on the tapes. Accordingly, the following comments, including decisions subject to periodic review, are offered to clarify normal practices and the procedures designed to benefit the majority of users.

4.1 The term "IBM-compatible," as used throughout this report, refers only to binary-reading IBM equipment and omits mention of binary-coded decimal (BCD) formats. Actually, CDC 1604 computer routines can be written to translate DATDC library tapes into a BCD format which can be read by computers such as the IBM 7070. However, as this report is being issued, no such requirement has been established.

4.2 The term IBM-compatible implies also that the end of each continuous string of data characters ("record") will be terminated by a frame called a "Longitudinal Redundancy Check Character" (LRCC), spaced 0.021 inch away from the last data character. This frame is written to be an even parity check of all previous bits recorded longitudinally along the tape, including the odd parity check bits. This is followed by 3/4-inch (or more, in some cases) of blank tape. Additionally, the end of a file is indicated by another frame, representing an octal 17, spaced 3/4-inch (or more) away from the LRCC. This end of file frame is also followed by an LRCC frame. The number of records per file depends on the length of each record. For this reason, a standard will not be set.

4.3 It may be practical for DATDC to supply computer-input tapes to some of the other users, provided they are willing to work with the DATDC computer-input format as carried on the Digital S tape of Figure 3. Specifically, since the University of California at La Jolla has a CDC 1604, DATDC could supply computer-input tapes written with FORTRAN 62 and with a label containing most of the information they desire.

4.4 Since it has been learned that several potential users of VELA-UNIFORM data have convenient access to IBM 1401 computers, DATDC plans to write a program for these computers which will enable them to read DATDC Digital B (library) tapes.

4.5 Practical considerations rule out the inclusion of all reference information on the label read into the tape, so that some information must be in an accompanying description. Further, the label format will change as experience dictates, so the contents of the label must be in some accompanying description.

4.6 Calibration data or scale constants in the labels would be useful to most users of the tapes. Actually, the most meaningful calibration would reference digital values back to earth motion, or at least to seismometer output. DATDC plans to include these data, although experience shows that in many cases they will be from 10 to 20 percent in error. It may be feasible to add comments on accuracy to the information accompanying the tape.

$2472_{10} = 4650_8 =$ 100 110 101 000 binary

Core Storage 000 000 000 000 000 000 000 000 000 000 000 000 100 110 101 000

Binary Tape

1	0	0	0	0	0	0	0	0	Data Bits
2	0	0	0	0	0	0	1	0	
3	0	0	0	0	0	0	1	0	
4	0	0	0	0	0	0	0	1	
5	0	0	0	0	0	0	0	0	
6	0	0	0	0	0	0	1	1	
7	1	1	1	1	1	1	0	1	Check Bits

← .005" →

← TAPE MOTION

Figure 1. CDC 1604 Binary Storage and Tape Representation of 2472 (decimal)

$2472_{10} = 4650_8 =$ 100 110 101 000 binary

Core Storage 000 000 000 000 000 000 000 000 100 110 101 000

Binary Tape

1	0	0	0	0	0	0	Data Bits
2	0	0	0	0	1	0	
3	0	0	0	0	1	0	
4	0	0	0	0	0	1	
5	0	0	0	0	0	0	
6	0	0	0	0	1	1	
7	1	1	1	1	0	1	Check Bits

← .005" →

← TAPE MOTION

Figure 2. IBM 700 and 7000 Series Computer Binary Storage & Tape Representation of 2472 (decimal)

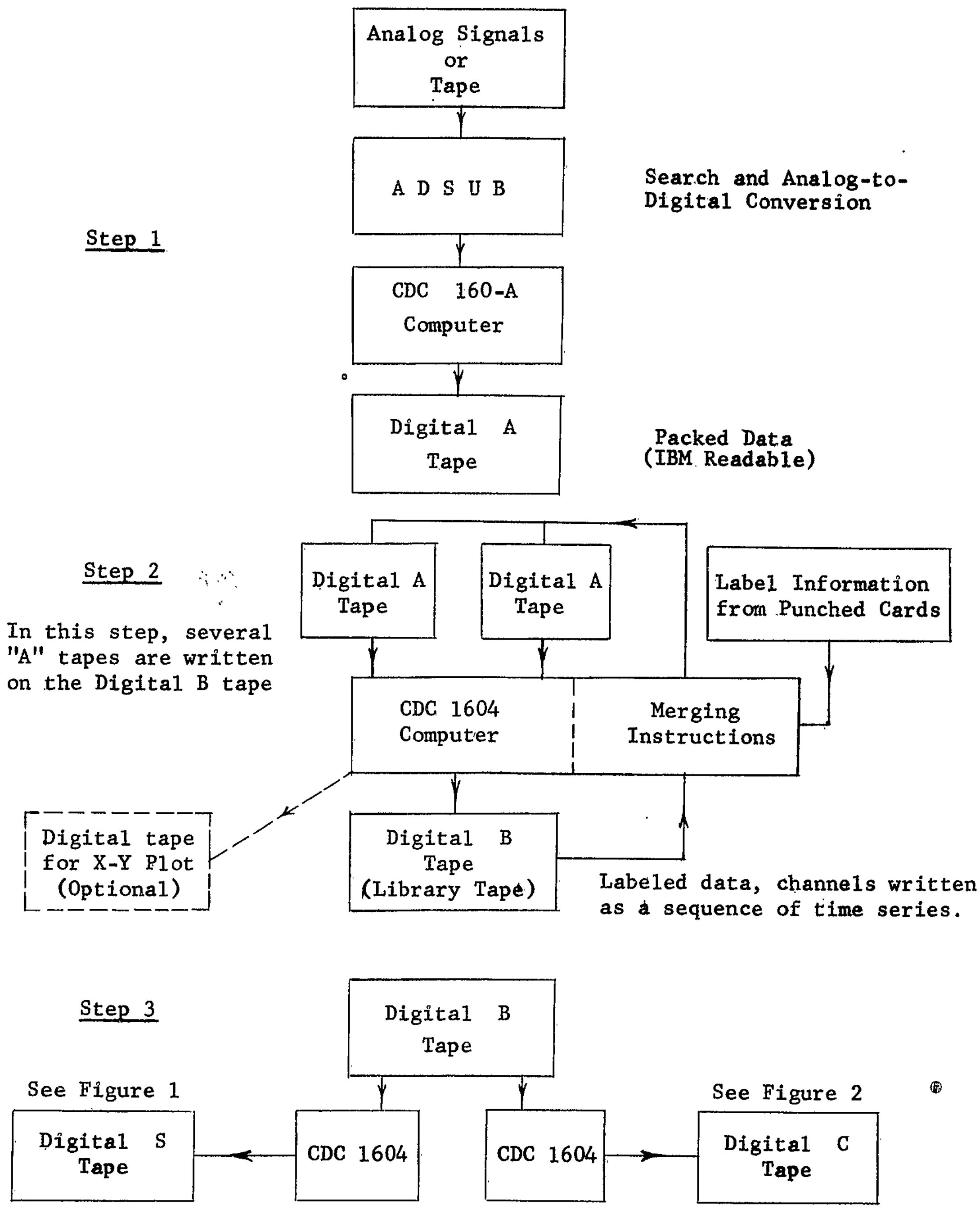

Figure 3. DATDC Analog-to-Digital Tape Process

APPENDIX

In the process of gathering information on which to base recommendations for a standard digital tape format, an AFTAC letter of 28 December 1962, A Proposed Standard Format for VELA-UNIFORM Magnetic Tapes, was directed to the organizations listed below. This letter described the procedures adopted by DATDC and requested comments.

Scripps Institute of Oceanography, La Jolla, California
University of California, Berkeley, California
California Institute of Technology, Pasadena, California
Stanford Research Institute, Menlo Park, California
Lamont Geological Observatory, Columbia University, Palisades, New York
Southern Methodist University, Dallas, Texas
Air Force Cambridge Research Laboratories, Bedford, Massachusetts
US Coast and Geodetic Survey, Washington, D. C.
US Geodetic Survey, Lakewood, Colorado
VELA Seismic Information Analysis Center (VESIAC), Ann Arbor, Michigan
The Geotechnical Corporation, Dallas, Texas
Texas Instruments, Inc., Dallas, Texas
Century Geophysical Company, Tulsa, Oklahoma

At the time of preparation of this report, comments had been received from the following organizations.

University of California, La Jolla, California (Scripps Institute of Oceanography)
University of California, Berkeley, California
California Institute of Technology, Pasadena, California
Stanford Research Institute, Menlo Park, California
Lamont Geological Observatory, Columbia University, Palisades, New York
Air Force Cambridge Research Laboratories, Bedford, Massachusetts
Texas Instruments, Inc., Dallas, Texas